The Baysüngür Quantum Geometry Framework (BQGF): A Singularity-Free Perspective on Gravitational Collapse

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Abstract

Classical General Relativity predicts spacetime singularities characterized by divergent curvature invariants, signaling the breakdown of the effective theory. In this work, we propose the Baysüngür Quantum Geometry Framework (BQGF), a phenomenological approach incorporating a fundamental minimal length scale. By constructing the Baysüngür Effective Metric Model (BEMM), we demonstrate that the spacetime geometry remains regular at the core. The framework further suggests a deterministic transition from gravitational collapse to expansion through a bounce mechanism, providing a consistent and singularity-free description of collapse.

1 Introduction

General Relativity successfully describes gravitational phenomena across a wide range of scales, yet it predicts spacetime singularities in regimes of extreme curvature, such as the interior of black holes. At these points, curvature invariants diverge and the classical description loses predictive power. Such divergences are widely interpreted as indications of the limitations of the effective theory rather than physical infinities.

The Baysüngür Quantum Geometry Framework (BQGF) is motivated by the assumption that spacetime possesses a fundamental minimal length scale, preventing the formation of zero-volume regions. Rather than modifying gravity perturbatively, BQGF introduces quantum-geometric corrections directly at the level of the effective spacetime geometry, ensuring regularity throughout gravitational collapse.

2 Effective Geometry and Regularity

Within BQGF, we define an effective radial coordinate

$$r_{\text{eff}} = \sqrt{r^2 + \alpha^2 \ell_p^2}, \tag{1}$$

where ℓ_p denotes the Planck length and α is a dimensionless parameter of order unity. This construction ensures that the effective volume element never vanishes.

The resulting Baysüngür Effective Metric Model (BEMM) is described by the line element

$$ds^2 = -f(r)\, dt^2 + \frac{dr^2}{f(r)} + r_{\text{eff}}^2\, d\Omega^2, \tag{2}$$

with

$$f(r) = 1 - \frac{2GM}{c^2 r_{\text{eff}}}. \tag{3}$$

A direct computation shows that the Kretschmann scalar remains finite in the limit $r \to 0$:

$$\lim_{r\to 0} K = \frac{48G^2M^2}{c^4(\alpha\ell_p)^6} < \infty. \tag{4}$$

Here, the term *singularity-free* refers to the absence of curvature divergences and geodesic incompleteness, rather than the removal of the coordinate origin. The classical singularity is thus replaced by a regular Planck-scale core.

3 Baysüngür Bounce Model

The presence of a minimal length scale implies effective quantum-geometric contributions that become significant at small radii. These contributions generate an effective repulsive behavior, halting collapse at a characteristic bounce radius,

$$r_{\text{bounce}} \approx (\alpha\ell_p^2 M)^{1/3}. \tag{5}$$

As a result, gravitational collapse undergoes a smooth and deterministic transition into an expansion phase. While the present work remains phenomenological, the existence of a regular core naturally suggests the possibility of unitary evolution through quantum-geometric degrees of freedom, motivating further investigation into microscopic realizations.

4 Observational Signatures

A regular interior structure modifies the propagation of perturbations near the core. In particular, partial reflections may give rise to late-time gravitational-wave echoes. The characteristic echo time delay can be estimated as

$$\Delta\tau \approx \frac{4GM}{c^3} \ln\left(\frac{r_s}{r_{\text{bounce}}}\right), \tag{6}$$

where r_s denotes the Schwarzschild radius.

For a black hole of mass $M = 10M_\odot$, this expression yields $\Delta\tau \approx 7.9\,\text{ms}$. Such a signal provides a potentially testable prediction for future interferometric observations.

5 Conclusion

The Baysüngür Quantum Geometry Framework offers a concise and consistent singularity-free description of gravitational collapse. By enforcing a fundamental minimal length scale, the framework ensures regular curvature invariants, geodesic completeness, and deterministic evolution. While the present approach is phenomenological, its robustness and observational implications make it a promising avenue for further exploration in quantum gravity and black hole physics.

References

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